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DRYING OF SANITARY-WARE USING MICROWAVE ENERGY

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Drying of sanitary-ware castings using microwave power was investigated with samples supplied by the manufacturer. Laboratory measurements showed that microwave heating could dry miniature castings four times faster than conventional electric heating. A demonstration of microwave drying for larger production-sized castings is recommended.

A large manufacturer of sanitary-ware (bathtubs, wash basins, toilets and sinks) contacted Ontario Hydro and requested assistance in exploring alternate methods of drying ceramic castings. Before firing, the ceramic castings must be completely dry. At present, drying in gas-fired ovens takes about 18 hours. Because of the long drying process, a large inventory of finished products is required to meet temporary increases in demand. The inventory requires a large storage area which is costly. Consequently, the company was looking for ways to accelerate the drying process, thereby reducing the inventory requirement. Through Jack Brown of Central Region, a meeting with the company was held. It was decided to evaluate the feasibility of using microwave or radio-frequency energy to dry the products. After a preliminary evaluation, it was shown that radio-frequency would be unsuitable for drying sanitary-ware because of product geometry. For a product to be processed by radio-frequency, it must have a regular shape, preferably with a rectangular cross-section. Irregularly shaped sanitary-ware is more suited for processing with microwaves.

job	file	date	report no.
740612-154-111	814.35	June 20, 1986	86-92-K

Slip Casting

A mixture of clay and water is used to form a "slip" which is poured into a plaster-of-paris mould. After an appropriate length of time, the clay settles against the wall of the mould, the water is drained and the mould is removed. The resultant clay or "green" body can be handled. This green body is dried in a gas-fired oven at 65°C for 18 hours. Then it is glazed and fired to produce the finished product.

At the request of the manufacturer, the investigation was limited to the drying of the green bodies.

Test Procedure

The samples of green bodies obtained from the manufacturer consisted of miniature rectangular tanks with lids and cylindrical shapes. These samples were used to represent the geometry of the actual products. The average moisture content of these samples was approximately 20% (by weight, dry basis).

The samples were dried in an industrial microwave chamber using different output powers and a conventional electric oven preheated to a temperature of 65°C. Sample mass was measured continuously in the microwave chamber and periodically in the conventional oven. Energy consumption for both heating units, drying times, microwave power levels and sample temperatures were monitored. In the conventional tests, no attempt was made to simulate the manufacturing conditions, apart from the approximate oven temperature.

Test Results

Table 1 is a summary of the test results.

Figure 1 graphically illustrates the moisture levels versus time for microwave and conventional drying.

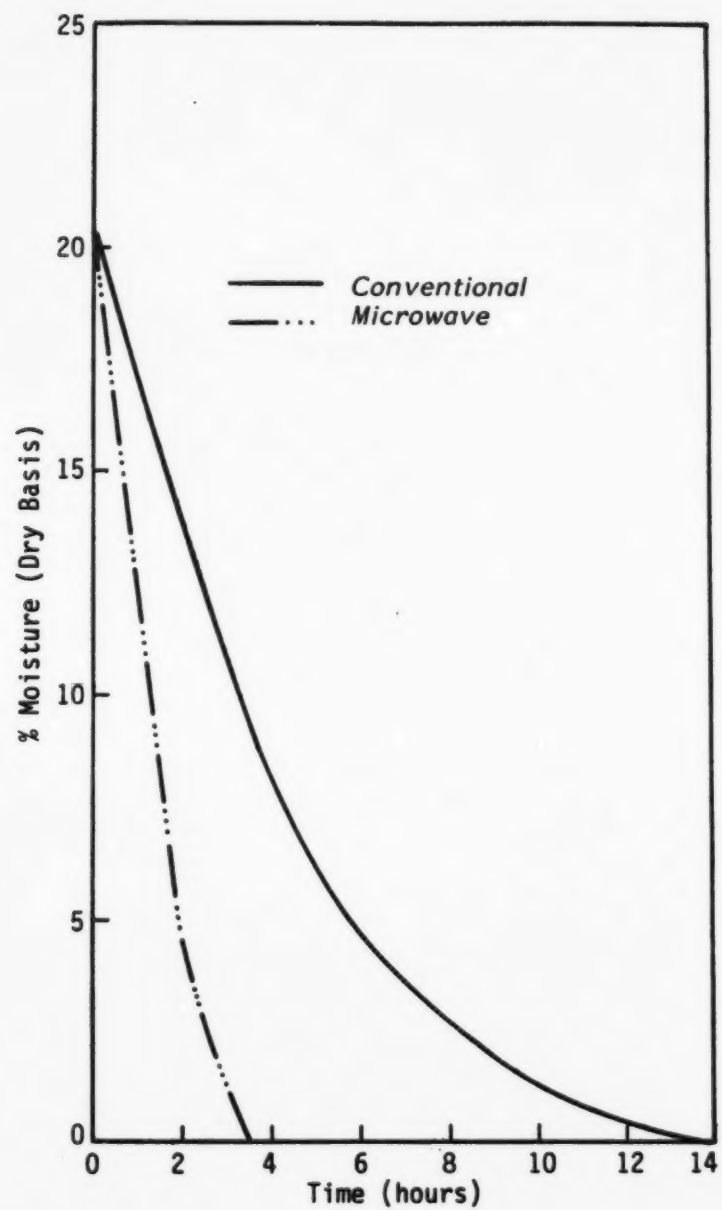


FIGURE 1
DRYING OF CERAMIC CASTINGS
CONVENTIONAL VS MICROWAVE HEATING
% MOISTURE VS TIME

TABLE 1 TEST RESULTS

DRYING OF CERAMIC CASTINGS

Drying Method	Product Description	Initial Mass(kg)	Final Mass(kg)	Time (min)	Energy Consumpt'n (kWh)	Comments
Microwave 1000 W	Rectangular Tank	1.06				Sample exploded
Microwave 700 W	Rectangular Tank	0.95				Sample exploded
Microwave 500 W	Rectangular Tank	0.97				Sample exploded
Microwave 400 W	Rectangular Tank with Lid	2.10	1.74	205	2.5	
Microwave 400 W	Rectangular Tank with Lid	2.10	1.75	204	2.4	
Conventional 65°C	Rectangular Tank with Lid	2.12	1.76	840	5.1	
Conventional 65°C	Rectangular Tank with Lid	2.12	1.76	840	5.0	

Discussion of Results

From Table 1 it can be seen that the output power level for microwave heating is important. For example, at power levels above 500W, the ceramic samples exploded due to internal vapour pressure build-up. However, at 400W, no explosion of samples occurred and no cracks were found in the dried product. Microwave drying took approximately three hours and twenty-five minutes to complete. In comparison, conventional drying took over fourteen hours.

It is estimated that a 32 kW microwave unit is needed to dry a batch of 10 toilet bowls in about 6 hours. The details of the calculation are shown in the appendix. The optimum drying rate for production-sized samples may be considerably faster than the 6 hours stated above. However, testing with these larger samples must be performed in order to determine this rate as there are geometric and scaling effects.

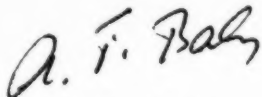
Conclusions

1. Microwave heating dried small ceramic castings four times faster than conventional heating.
2. The exact microwave drying rate of production-sized castings can only be established through physical testing. (OHRD has larger microwave equipment on order).
3. Excessive microwave power output will cause product damage to ceramic castings.

Recommendation

It is recommended that a demonstration of microwave drying be conducted using production-sized sanitary ware.

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APPENDIX

Sizing of Microwave Unit

The following section illustrates the steps required to approximate the size of microwave equipment for the drying application.

- a) Theoretical energy needed
to evaporate M_1 kg of water = Q

$$= M_1 \times C_{p,w} \times (100-T) + M_1 \times L_v + M_2 \times C_{p,c} \times (100-T)$$

where T is the ambient temperature ($^{\circ}\text{C}$)

M_1 is the mass of water evaporated (kg)

M_2 is the mass of ceramic sample (kg)

$C_{p,w}$ is the specific heat of water (kJ/kg $^{\circ}\text{C}$)

$C_{p,c}$ is the specific heat of ceramic (kJ/kg $^{\circ}\text{C}$)

L_v is the latent heat of water (kJ/kg)

- b) The time required to evaporate M_1 kg of water from a ceramic sample using a microwave oven is shown below:

$$t = \frac{Q}{H(1-\rho^2)} \times \frac{Wh}{3600 \text{ J}}$$

where t is the time required (h)

H is the output of the microwave unit (kW)

ρ is the reflection coefficient (dimensionless)

ρ is measured by experimentation using the following relationship:

$$\rho^2 = \frac{\text{reflected microwave power}}{\text{incident microwave power}}$$

The following information pertains to drying of toilet bowls:

Each toilet bowl (green body) weighs 25.5 kg with approximately 4.5 kg of water. The specific heats are 0.94 kJ/kg°C and 4.19 kJ/kg°C for ceramic and water respectively. From the experiment performed in the laboratory it is estimated that ρ^2 is approximately equal to 0.80. Using the above quantities, it can be estimated that a 32 kW microwave unit is needed to dry 10 toilet bowls in about 6 hours.